Resilience in adversity: Rebuilding Acapulco after the catastrophe of Otis

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ABSTRACT

Acapulco, a global tourist destination, faces challenges from frequent hydrometeorological events. This article examines its vulnerability and governmental responses to hurricanes. The study focuses on analyzing resilience in adversity through the case of Acapulco after Hurricane Otis. The objectives were to synthesize vulnerability and governmental responses to natural events in Acapulco, emphasizing the importance of sustainability and resilience. The methodology involved collection official data on climatic events, economic losses, and governmental responses. The evolution of the population and affected infrastructure was analyzed, focusing on specific cases such as Hurricane Otis. The results reveal an increase in vulnerability due to population growth and urban development without considering climatic risks. Despite governmental efforts in hurricane response, a lack of preparedness and risk communication impacted the city's resilience. Therefore, the study will aim to extract lessons learned from the experience of Acapulco to provide practical recommendations for enhancing resilience in other communities facing similar disasters. Conclusions are as follows: 1) Acapulco's vulnerability is heightened by growth without considering climatic risks; 2) governmental responses, though coordinated, need improvement in preparedness and risk communication; and 3) the key to sustainability lies in joining efforts, reducing vulnerability, and promoting resilience to extreme climatic events and 4) informing about the future strategy for disaster management and reconstruction in affected communities.

Keywords: Acapulco,resilience to disasters, government response, urban sustainability, climate vulnerability

1. INTRODUCTION

In 2017, the World Meteorological Organization (WMO) "included... the names Max, Norma, and Otis in the list of Pacific hurricanes for 2023" (Andrew, 2023:1) [1]. In this geographical area, there is a Hurricane Committee dedicated to the North America, Central America, and Caribbean region. This committee is composed of the National Meteorological and Hydrological Services that are part of the WMO Regional Association IV.

On average, 84 named tropical cyclones form worldwide each year. Over the past 50 years, these cyclones have caused a daily average of 43 fatalities and $78 million in U.S. dollars in losses, representing one-third of the deaths and economic losses from weather, climate, and water-related disasters, according to statistics compiled by the WMO for the period from 1970 to 2019. However, the number of fatalities has significantly decreased due to improvements in forecasts, warnings, and disaster risk reduction measures facilitated by the WMO Tropical Cyclone Programme (Andrew, 2023:2) [1].

In Mexico, the National Meteorological Service of the National Water Commission (Conagua), in collaboration with the National Hurricane Center of the United States of America and the Specialized Meteorological Center of the WMO in Miami, "warns that

catastrophic tides and deadly winds may occur, as well as flash floods in urban areas" (Reliefweb, 2023) [2]. Additionally, they were monitoring the formation of a tropical depression in the Pacific Ocean.

According to the National Meteorological Service, the cyclone in question is classified as the most powerful recorded in recent memory, surpassing even the intensity of Hurricane Patricia in October 2015, which impacted the state of Jalisco, Mexico (BBC Mundo) [3].

The classic season for the formation of tropical cyclones in Mexico in the Atlantic Ocean includes the Gulf of Mexico, where tropical cyclones form and impact the eastern coast of Mexico, especially the Gulf states such as Tamaulipas and Veracruz. "The season begins in June and ends in November, with the highest frequency occurring in September" (Matías Ramírez, 1998:9) [4]. Additionally, another cyclone-generating center is located in the Caribbean Sea, which can affect the Yucatán Peninsula and the Florida Peninsula in the United States of America.

In the Pacific Ocean, the epicenter for the formation of tropical cyclones is located in the Gulf of Tehuantepec. The effects of these cyclones cover an extensive area, impacting regions from Chiapas to Baja California. Although less frequent, another formation center is found in the Gulf of California, with notable impacts on the surrounding coastal regions. Recent research, such as the study by Gao et al. (2022) [5], suggests that the El Niño phenomenon in the central-north Pacific plays a crucial role in the development of tropical cyclones in this region.

La historical geography of hurricanes in Acapulco, Guerrero, greatly contributes to the uniqueness of Otis as a historical hurricane, highlighting the unlikely occurrence of direct impacts in this region. Despite Acapulco being in a solidly tropical geographical position at a latitude of 17 degrees north, bathed by extremely warm waters, the southern coast of the Mexican Pacific rarely experiences hurricanes that make landfall. Instead, the prevailing eastward winds characteristic of this latitude direct hurricanes toward the west-northwest, following a path approximately parallel to the coast.

The probability of a hurricane changing its course to the north and northwest increases towards the end of the season. This change is attributed to the southern penetration of intense low-pressure troughs, necessary to induce such directional currents. This phenomenon underscores the exceptional nature of Otis in deviating from the historical trend, making it a climatically significant event for the region of Acapulco.

Reliable satellite records of tropical cyclones in the Eastern Pacific date back only to the early 1970s. Despite this temporal limitation, it is evident that Acapulco rarely experiences direct impacts from hurricanes. The last hurricane of significant intensity to make landfall near the city was an unnamed storm in 1951, which followed a southeast to northwest trajectory across Acapulco, with estimated maximum sustained winds of 75 knots or 85 mph (category 1). During that period, the population was around 30,000 inhabitants, as this preceded the mid-century tourism boom.

In 1973, Tropical Storm Claudia made landfall approximately 30 miles east of Acapulco, bringing heavy rains to southern Mexico. However, apart from this event, there are no records of tropical storms or hurricanes making landfall within 50 miles of Acapulco, according to Henson et al. (2023) [6]. This pattern reinforces the notion of the rarity of direct impacts from tropical cyclones in the region, contributing to the climatic uniqueness of Acapulco's situation.

In 1997, the devastating Hurricane Pauline, which reached its maximum strength as a Category 4 at sea, made landfall over 200 miles east of Acapulco as a Category 2 hurricane. Subsequently, it followed a classic path along the coast inland, leading to a decrease in its intensity, although it dumped considerable amounts of rain along its path. When Pauline was close to reaching the minimum hurricane strength, it passed directly north of Acapulco.This event resulted in the destruction of approximately 5,000 homes due to sudden floods and landslides in various areas of the port. It affected high-altitude areas with steep slopes and impoverished slopes of El Veladero National Park located near the city center. Consequently, the majority of Acapulco residents were deprived of electricity and water. The magnitude of the tragedy is evident in the loss of up to 500 lives, highlighting the severe humanitarian impact of Hurricane Pauline on the Port of Acapulco Rodríguez Esteves (2017) [7].

2. MATERIAL AND METHODS

The materials used in the study include documents, books, and specialized articles on climate change, risk, and hurricanes that have affected Acapulco from 1921 to 2023. Additionally, specialized literature on risk geography, sustainability, and tourism was consulted. To carry out the fieldwork, equipment was employed, including cameras for visual documentation, tools for the collection of qualitative and quantitative data, as well as a field log. As for the instruments, sources of specialized literature, electronic libraries, and databases were consulted for desk research. During the fieldwork, photographic cameras were used to capture visual observations. Furthermore, a statistical method was applied along with spatial analysis tools, complemented by qualitative, quantitative, and cartographic techniques to achieve a comprehensive approach in the collection and analysis of data.

The working method is related to the fundamentals of Landscape Geography to achieve sustainability. The landscape is crucial because: a) it reflects the physical potential of the territory, b) it is a biological response on which humans act, c) it allows characterizing the territory, d) the fundamental data to classify the geographic enclave is the landscape, and e) it is the backbone of any study that allows obtaining a deep understanding of the territorial system (Niño-Gutiérrez, 2022) [8]. The Integrated Landscape Analysis method is supported by qualitative techniques such as participant observation and, in a quantitative way, with cartographic techniques. The resulting synergy is useful because it allows correlating the elements of nature with the existing environmental problems in Acapulco, Guerrero, Mexico.

3. METHODOLOGY

The methodology employed in the development of this contribution encompassed a series of fundamental steps, from the initial conception of the study to the final drafting of the article. The main steps are detailed below: Conception and Planning: In the initial phase, a thorough review of the literature related to climate change and hurricanes that have impacted Acapulco from 1921 to 2023 was conducted. The focus was on social resilience in the context of hurricane disasters, specifically in the case of Acapulco. This review contributed to defining the scope, objectives, and variables of the study. The materials used included previous research documents on Acapulco, statistics and demographic data from the municipality, as well as geospatial information, maps, and records of past climatic events.

Data collection: For data acquisition, an exhaustive search for printed and digital information on the daily development of Hurricane Otis and its effects on the economic, tourist, social, and environmental sectors was carried out. This phase was characterized by the collection of qualitative and quantitative data, allowing for a thorough exploration of the topics under study and article writing phase: The final stage involved the drafting of the article following

the style and format guidelines provided by the Journal's template for this manuscript. Standard sections, such as introduction, methodology, results, discussion, and conclusions, were included. A comprehensive review of the manuscript was conducted to ensure the coherence and accuracy of the findings and their presentation.

4. CONCEPTUAL FRAMEWORK

Vulnerability 'can be understood as the propensity of a society or community (Acapulco) to suffer damage due to the presence of a disruptive agent, in this case (hurricanes)' (Rodríguez Esteves, 2017: 137) [7]. This focuses on the case of Otis and its effects on Acapulco, which is a dynamic context from one community to another.

During the development of Hurricane Otis, these weaknesses manifested particularly in various sectors, reflecting the changing nature of the community context. The identified incapacities are associated with different dimensions of vulnerability, encompassing physical, social, economic, environmental, political, cultural, and geographical aspects, among others. This multidimensional approach underscores the complexity of factors contributing to Acapulco's vulnerability to extreme climatic events such as Hurricane Otis.

A tropical cyclone is a meteorological system of low pressure that forms over warm ocean waters and is characterized by the presence of organized circular winds. In Mexico, these systems are classified as hurricanes or tropical storms and can arise in both the Pacific and the Atlantic, as noted by Niño Gutiérrez et al. (2017) [9].

The formation of a cyclone involves several key factors. Winds are generated as warm air over the ocean rises, creating a low-pressure area. This void is rapidly filled by surrounding air, giving rise to strong winds circulating counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. These characteristic wind movements are essential for the definition and evolution of a tropical cyclone.

In addition to the winds, two additional factors develop simultaneously in the formation of a tropical cyclone: precipitation and high waves. The combination of strong winds and the evaporation of warm ocean water contributes to the formation of high waves, as noted by Niño-Gutiérrez et al. (2018) [10]. Tropical cyclones are known for generating intense precipitation. The resulting torrential rains can lead to flooding, posing a significant risk to affected coastal areas. The combination of these elements—winds, precipitation, and waves—defines the complexity and potential impact of tropical cyclones in the affected regions.

Climate change refers to long-term alterations in Earth's climate patterns, primarily attributed to human activities that lead to the accumulation of greenhouse gases. This phenomenon causes a widespread increase in temperatures, changes in sea levels, extreme weather events, and disruptions to ecosystems (Niño-Gutiérrez, 2020) [11]. The burning of fossil fuels, deforestation, and other industrial activities are major drivers of climate change. Its impacts include threats to food security, an increased risk of natural disasters, and the loss of biodiversity. Combating climate change involves reducing greenhouse gas emissions, adapting to ongoing changes, and seeking sustainable solutions on a global scale.

Resilience related to Hurricane Otis in Acapulco refers to the city's capacity to withstand, recover, and adapt to the impacts of the hurricane. It involves the ability of the population and local infrastructure to face and overcome the adverse consequences of the phenomenon, including damage to infrastructure, economic losses, and social challenges. In

this context, resilience implies an effective and coordinated response from authorities to the emergency, as well as the community's capacity to adapt to sudden changes, learn from past experiences, and work towards reducing future vulnerabilities. The lack of preparation and risk communication negatively impacted Acapulco's resilience, highlighting the need to strengthen these aspects to build a more resilient community against extreme climatic events such as Hurricane Otis.

Negentropy, contrasting with entropy, plays a fundamental role in the vitality and continuity of organizations, especially within the framework of General Systems Theory. It is argued that organizations that do not renew themselves face the risk of disappearance; therefore, evolving towards a state of greater order and organization is crucial. Originating in physics, this concept represents a force against chaos and becomes an essential element for the necessary transformation in the present (Ruffini & Blanco, 2022) [12]. In complex systems, negentropy is revealed as essential for the sustainability and adaptability of contemporary organizations.

In an environment characterized by its unpredictability, negentropy emerges as an invitation to make significant changes. In simpler terms, in a constantly changing world, maintaining a sense of control, to the extent possible, is needed. This principle finds application in the tourism industry, which, being an open system, allows the entry of negative entropy. This phenomenon facilitates the search for a new balance in tourist destinations that were once considered paradisiacal. The introduction of negentropy thus becomes a vital mechanism to preserve and renew the vitality of these destinations.

5. THEORETICAL FRAMEWORK

Ann Masten's resilience theory highlights individuals' ability to recover and adapt positively after facing adversities. According to this theory, resilience is based on a combination of internal and external factors. Internal factors include personal traits such as self-esteem, autonomy, and the ability to regulate emotions. External factors involve social support, the existence of quality relationships, access to resources and opportunities, and a stable and secure environment. Masten's resilience theory emphasizes the importance of the interaction between personal and contextual factors to promote resilience in individuals and communities (Sánchez, 2016) [13].

On the other hand, C. S. Holling's ecological resilience theory focuses on the resilience of ecosystems. It proposes that ecological ecosystems go through cycles of change, adaptation, and transformation in response to disturbances or environmental changes. According to this theory, resilient ecosystems have the ability to absorb and quickly recover from disturbances while maintaining their basic structure and functions. Ecological resilience is based on biological diversity, connectivity between different habitats, the presence of positive and negative feedback mechanisms, and the system's learning and adaptation capacity. The ecological resilience theory emphasizes the importance of conserving and restoring the health and integrity of ecosystems to address the challenges of climate change and ensure environmental sustainability (Bocco, 2019) [14].

Climate change refers to long-term changes in Earth's climate patterns. These changes are due to both natural factors and the influence of human activities, particularly the emission of greenhouse gases. The primary driver of current climate change is the increase in the concentration of greenhouse gases in the atmosphere, such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). These gases trap solar heat in the atmosphere, causing an increase in the planet's average temperature, known as global warming (Griffith et al., 2012) [15].

The effects of climate change manifest in various ways, including increased average temperatures, melting ice caps and glaciers, rising sea levels, ocean acidification, altered precipitation patterns, and the intensification of extreme weather events such as droughts, floods, storms, and heatwaves. These changes have significant impacts on ecosystems, biodiversity, the availability of natural resources, agriculture, human health, and human settlements. Additionally, climate change poses socio-economic and ethical challenges as it disproportionately affects vulnerable communities and amplifies existing inequalities (Islam et al., 2022) [18].

6. RESULTS

The Pacific region in Mexico has experienced some of the most intense hurricanes between 1957 and 2023. Typically, around four hurricanes making landfall are recorded every three years in this area. However, in October of this year, three impacts have occurred, highlighting the exceptional cyclonic activity in the region.In particular, Hurricane Lidia struck the Pacific coast of Mexico approximately 35 miles south-southwest of Puerto Vallarta just two weeks before the arrival of Hurricane Otis. Lidia reached Category 4 with winds of 140 mph and rapidly intensified, increasing its winds by 65 mph in the 24 hours leading up to landfall. At that time, Lidia was tied as the third-strongest hurricane ever recorded in the history of the Mexican Pacific.

Hurricane Otis, which followed Lidia, recorded even more intense winds, reaching 165 mph. This situation underscores the remarkable intensification of hurricanes in the region during this specific period. Other notable hurricanes in the history of the Mexican Pacific include Patricia in 2015 (150 mph), Madeline in 1976 (145 mph), Kenna in 2002 (140 mph), Hurricane 12 in 1957 (140 mph), Hurricane Mexico in 1995 (140 mph), and Hurricane Lidia in 2023 (140 mph), all with significantly strong winds. These events highlight the importance of closely monitoring cyclonic activity in this region prone to intense impacts (Figure 1).

As of the date in 2023, the northeastern Pacific region has experienced notable cyclonic activity, recording eight Category 3 or higher hurricanes. This figure is nearly double the expected average for this point in the season, which is 4.6. Among these hurricanes, five have reached Category 4, while two have reached Category 5, marking a particularly intense season in terms of wind strength.A key indicator of basin activity is the Accumulated Cyclone Energy (ACE), which currently reaches a total of 158. This index places the 2023 hurricane season as the most active since 2018 when an ACE index of 318 was recorded (Henson et al., 2023) [6. This increase in cyclonic activity suggests favorable conditions for the development and strengthening of hurricanes in the northwestern Pacific region during this year.

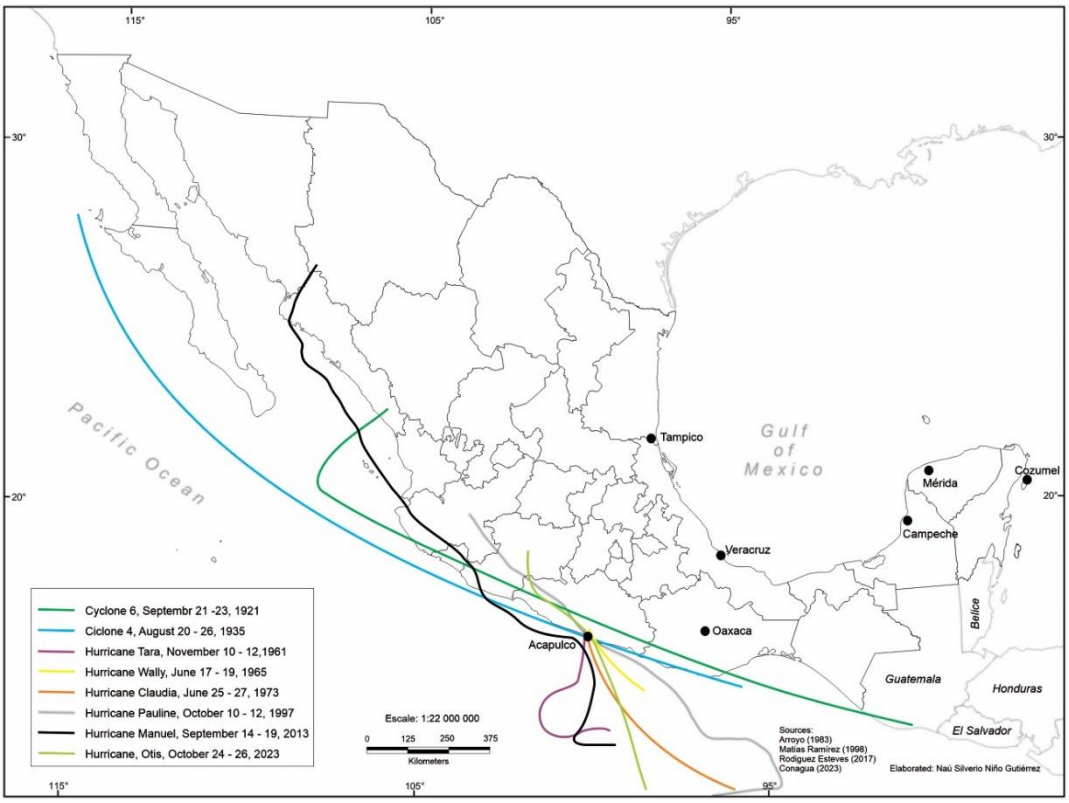

Figure 1. Hurricanes that have impacted Acapulco, Guerrero 1921-2023.
Source: Matías Ramírez (1998) [4]; Arroyo, (1983) [16]; Rodríguez Esteves (2017) [7]and ServicioMeteorológico Nacional-Conagua (2023) [17].

It is interesting to observe other documented hurricanes in the region that have left their mark over time. Below is a list of some historical events: *i)* Cyclone 6 (September 21-23, 1921): This cyclone, recorded in September 1921, is part of the cyclonic history of the region, although specific details of its impact and characteristics may vary; *ii)* Cyclone 4 (August 20-26, 1935): This cyclone, felt during August 1935, marked another event in the history of hurricanes in the area; *iii)* Hurricane Tara (November 10-12, 1961): Another example of the variability and occasional intensity of cyclonic events in the region; *iv)* Hurricane Wally (June 17-19, 1965): Contributed to the series of cyclonic events that have affected the region over the years and *v)* Hurricane Claudia (June 25-27, 1973): Also adds to the list of significant cyclonic events that have impacted the region. These historical events, documented by Matías (1998), provide a more comprehensive insight into the frequency and variety of hurricanes that have affected the region over time.

On the Sunday of October 2023, the High-Resolution Forecast Guidance (HFG) models (Balaguru et al., 2023) [19] and satellite images did not clearly anticipate the catastrophic strengthening of Tropical Storm Otis. However, the personnel of the United States National Hurricane Center, which is also the Regional Specialized Meteorological Center of the UN agency (Mongabay Latam, 2023) [20], were closely monitoring the situation.

On Monday, October 23, nationwide forecasts predicted heavy rains in the state of Guerrero, covering the municipalities of San Marcos (Costa Chica), Acapulco, Coyuca de Benítez, San Jerónimo, Atoyac de Álvarez, and Tecpan de Galeana (Costa Grande). This forecast

indicated the imminent threat of adverse weather conditions in the region and called for the attention and preparation of the affected communities.

On Tuesday, October 24, 2023, the tropical storm underwent rapid intensification, transforming into a Category 2 hurricane at 13:00 hours. Subsequently, at 15:00 hours, the hurricane escalated to Category 3, reaching Category 4 at 18:00 hours, and finally evolving into Category 5 at 21:00 (CienciaUNAM, 2023) [21].

Climate experts and atmospheric science researchers are currently investigating the surprising metamorphosis of Hurricane Otis. The main explanation for this phenomenon focuses on the influence of the El Niño season, according to NASA data (2006), and the rise in ocean temperatures. Prominent researchers from institutions such as the Center for Scientific Research and Higher Education of Ensenada (Cicese) and the Institute of Atmospheric Sciences at the National Autonomous University of Mexico (UNAM) have emphasized the relevance of these factors in the hurricane's transformation (Mongabay Latam, 2023) [20].

At 21:30 hours on the same day, Mayor Abelina López locally reported that Hurricane Otis had intensified to Category 4, projecting its evolution to the maximum classification, Category 5, according to the Saffir-Simpson scale, before impacting the Guerrero coast. Faced with this situation, the mayor strongly recommended that the population stay in their homes. The projection indicated that by 23:30 hours, the force of gusts up to 330 km/h would be experienced, as stated by Maestra Alejandra Méndez Girón, the general coordinator of Mexico's National Meteorological System (SMN) (Mongabay Latam, 2023) [20].

Indeed, between 23:30 and 02:30 hours on Wednesday, October 25, 2023, the most intense winds were recorded. In the light of dawn, the impacts of the hurricane were evident, with roofs, sheets, water tanks on the ground, flooding, and fallen trees everywhere. Additionally, severe damage was reported in infrastructure, the electrical system, telecommunications, and internet service, resulting in the absence of water, electricity, and communications, summarizing the magnitude of the destruction (BBC Mundo, 2023) [3].

The rapid intensification of Otis is attributed to several factors. Despite being a small system, with hurricane-force winds extending only 30 miles from its center, small hurricanes can experience more significant changes in intensity, either strengthening or weakening, depending on the present atmospheric conditions.In the specific case of Otis, the rapid intensification was favored by the exceptionally warm sea surface temperatures, ranging between 30 and 31 degrees Celsius (86-88 °F). These temperatures were approximately 1 degree Celsius (1.8 °F) above the average recorded between 1991 and 2020. The thermal anomaly in the waters where Otis developed is directly linked to the warmer temperatures recorded in Mexico during the month of September.

This warming of the sea waters, in turn, was partially associated with the natural phenomenon of El Niño, a climate pattern that influences global weather conditions. The influence of El Niño was amplified by the phenomenon of global warming caused by human activity. Together, these conditions provided the conducive scenario for the rapid intensification of Otis, demonstrating the interconnection between natural climatic events and disturbances derived from human activities.

The crucial element in Otis's rapid intensification lay in the presence of a robust band of winds, known as the jet stream, intrinsic to the air current flowing rapidly north of Otis. While the hurricane absorbed warm and humid air from the surface, lifting it into its eye, the powerful winds of this jet stream acted as a ventilation system for the meteorological system.

This process bears similarities to ventilating a fire, with the exception that, in the case of a hurricane, the additional "oxygen" provides thermal energy to the hurricane as it condenses, releasing the latent heat absorbed during the water vapor's evaporation phase.

Otis's ventilation by the jet stream not only served as a source of thermal energy but also stimulated ascent, facilitating the development of storms around the hurricane's center (Henson et al., 2023) [6]. This dynamic mechanism underscores the complexity of interrelated factors influencing hurricane intensification and highlights the importance of understanding the interaction between meteorological systems to predict extreme weather events.

According to meteorological tracking, at 00:25 in the early morning of October 25, 2023, Hurricane Otis, classified as a Category 5, directly impacted Acapulco with sustained winds of 270 km/h. Subsequently, at 03:00 AM, the hurricane's intensity decreased to Category 4. However, this event caused significant consequences, including the collapse of 50 high-voltage towers. Otis generated substantial damage to public hospitals as well as in 909 educational centers with differentiated damages out to total of 1224 schools survived according to the head of the Secretariat of Public Education (SEP), Letizia Ramírez Amaya (Hernández, 2023) [22], resulting in the cancellation of in-person and online classes from October 25 to November 27th, 2023.

By 09:00 AM, Otis had diminished to a Category 1 hurricane, and by noon, its strength further reduced, transforming into a low-pressure system. However, at 3:00 PM on the same day, October 25, the impact continued with the overflowing of the Papagayo, Balsas, and Sabana rivers, as well as landslides on the Autopista del Sol. Scenes of chaos were observed, with vehicles, furniture, dead animals, trees, and signs being carried away by the floods.

In this context, the World Meteorological Organization (WMO) emphasized the increasing vulnerability of societies and economies to high-impact weather phenomena. The WMO highlighted the importance of the international initiative 'Early Warning for All,' which aims to ensure the protection of all inhabitants worldwide through early warnings, including small island developing states on the front lines of climate change (Reliefweb, 2023) [2]. This initiative underscores the urgent need to strengthen early warning systems to mitigate the adverse impacts of extreme weather events.

The passage of Hurricane Otis had several notable effects in the region, including damages to homes and 47,627 commercial premises (Cedeño, 2023) [23] with affected facades, as well as reports of looting in various areas of the port of Acapulco. Additionally, the suburban area experienced flooding due to the overflowing of rivers and streams (Figure 2).

> According to the National Aeronautics and Space Administration (NASA), the National Hurricane Center (NOAA), and the Central Pacific Hurricane Center of the United States National Weather Service, Hurricane Otis set several records. It is the fastest-strengthening tropical storm ever recorded in the Northeast Pacific, according to modern records. It is the first Category 5 hurricane to make landfall on the Pacific coast and exhibited the fastest intensification ever observed in modern records. It ranks as the 4th tropical cyclone with the fastest winds globally and is the 2nd hurricane with the highest recorded wind speeds in America. Its gusts reached 330 kph, making it one of the 15 most powerful ever measured at ground level worldwide (Olivares, 2023, p.1) [24].

Fig. 2. Effects of Hurricane Otis on a subdivision in Acapulco, Guerrero
Source: photography of the authors

Given the magnitude of the situation, an order was issued from the National Palace for the deployment of the armed forces. The Mexican Army, Navy, and National Guard were mobilized to provide support and assistance in rescue and relief efforts for the affected population. This deployment aimed to mitigate the immediate impacts of the disaster, coordinating efforts to safeguard the safety and well-being of the inhabitants affected by the hurricane. The federal government, through the Ministry of Welfare, provided support to hotels and small businesses, including Nafin credits for small and medium-sized enterprises, a 50% interest subsidy on private bank loans for 377 hotels in Acapulco, and a deferral of payment of employer contributions to the Mexican Social Security Institute (IMSS) and the National Workers' Housing Fund Institute (Infonavit) for 6 months. Additionally, 26,634 producers and 8,000 fishermen received an additional support of 7,500 pesos each, amounting to a social investment of 259.6 million pesos (Ministry of Welfare, 2023) [25].

Authorities from the Federal Electricity Commission (CFE) managed to restore the electricity service in Guerrero in just 7 days after Hurricane Otis caused significant damage to a substantial part of the electrical system (CFE, 2023) [26]. In the recovery process, the Federal Electricity Commission (CFE) adopted a strategy focused on prioritizing the restoration of service to critical facilities such as hospitals, gas stations, public safety and civil protection offices, as well as water pumping stations. To carry out this task in such a short period, a contingent of more than 2,900 workers was mobilized, supported by 283 cranes, 875 vehicles, 147 emergency power plants, 38 lighting towers, and 7 helicopters. In addition, over 3,639 tons of materials were transported, supplementing the 3,500 already located on-site (*Ibídem*, 2003). This coordinated effort and the rapid mobilization of resources demonstrated the effectiveness of CFE's response in restoring electrical supply in the affected region for more than 200,000 families (Rivera & Stevenson, 2023) [27].

The National Institute of Public Health (INSP) emphasized the need for a unified and centralized coordination to address the emergency generated by Hurricane Otis. In order to restore public services and provide assistance to the affected population, a command center led by federal authorities was established in the city of Acapulco. The Ministry of Health, through the Public Health Incident Management System, activated an emergency response team involving the National Health System. This team includes the General Directorate of Epidemiology, IMSS-Bienestar, the Federal Medical Emergency Medical Services Regulatory Center, and the National Center for Preventive Programs and Disease Control.

Given the complexity of the situation, the priority is focused on executing systematized actions with a common goal: the protection of the population (INSP, 2023) [28]. This comprehensive strategy highlights the importance of interinstitutional coordination and the implementation of specific measures to ensure the safety and well-being of the community affected by the natural disaster.The intense winds generated by Hurricane Otis caused severe damage to the vegetation of deciduous lowland jungle, shrubs, bushes, and riparian vegetation located on the surface of the Pacific coast and lagoon in Tecomate (San Marcos) and Tres Palos (Acapulco). "It struck the rocky areas of the Pacific Ocean beaches where various species of fish, crustaceans, and worms reside, generating intense currents that disrupted marine ecosystems, explained David Salas, a specialist in physical oceanography from the Institute of Marine Sciences and Limnology, UNAM" (Cedeño, 2023, p. 1) [23].

Landslides were also recorded along the “Highway of the Sun”, specifically in sections like Dos Arroyos in the Acapulco-Chilpancingo route. These adverse weather conditions also resulted in the flooding of neighborhoods such as Emiliano Zapata and Ciudad Renacimiento, where the water level reached up to 70 cm in height on dry land. Additionally, the impact extended to the coast and the sea, from Caleta and Caletilla to Roqueta Island, covering Boca Chica and the mouth.The hurricane gusts impacted from Icacos Beach to Caleta, and even extended to Pie de la Cuesta, heading towards the municipality of Coyuca de Benítez, Guerrero. This extensive area was affected, causing damage to hotels, condominiums, homes (Figure 3), restaurants, commercial premises, and other infrastructure along its path. The magnitude of the impact highlights the extensive path of destruction caused by Hurricane Otis in various areas of the region.

The powerful winds of the storm, along with the high waves, caused the flooding of boats located at the coastal dock, resulting in the unfortunate loss of lives of some sailors. The coastal area experienced significant damage to public services, with ceiba trees (*Ceiba pentandra*) and amates (*Ficus sp*.) uprooted from the roots. Palm trees, which partially acted as a brake for the wind speed, were broken or left leaning. The accumulation of debris, branches, and waste contributed to the presence of garbage in the streets of residential areas and hotels in the port of Acapulco. The striking devastation in the coastal area

illustrates the ferocity of Hurricane Otis and its harmful consequences on various aspects of the environment.

Fig. 3. Garbage, flooding, and tree damage in a residential complex in Acapulco
Source: photography of the authors

The damage to educational infrastructure affected centers in Acapulco and Coyuca de Benítez, leading to the interruption of academic activities at all levels. One month into the coordinated efforts among the three levels of government to assist the population affected by Hurricane Otis..." (Olivares, 2023). It was on November 27, 2023, when the National Technological Institute of Mexico, located in Acapulco, resumed classes, followed shortly after by the Autonomous University of Guerrero, which returned to classes on December 4th.The health infrastructure also experienced the impacts of Hurricane Otis. This is why local medical staff had to seek external support from 1,276 healthcare professionals (Robles, 2023, p. 9). Medical personnel worked to attend to fractures, injuries, and wounds of various individuals seeking help, despite the lack of electricity, telephone service, and internet in the area.

Fishing activities were interrupted, with more than 600 boats stranded in the port. Among them, 300 vessels were destroyed, with their engines rendered unusable, and over 300 boats ended up sinking. Significant losses were recorded in the agricultural sector, with approximately 500,000 hectares of staple crops such as corn and beans affected by the passage of Otis. Additionally, the hurricane wreaked havoc on 400,000 hectares of palm orchards in full production between Acapulco, Coyuca de Benítez, Benito Juárez, and San Marcos.In the ecological-environmental realm, the Mexican Ecological Movement estimates that habitat recovery will take at least 20 years. This is due to the considerable number of trees and palms that were uprooted, broken, or cut in extensive areas of tropical jungle. Additionally, fruit trees such as mangoes, tamarinds, and even banana plantations were affected.

According to the Government of the state of Guerrero, the tourist economic impact in the region reached the amount of 6 million pesos in 2023. With a flow of 977 thousand people and an average hotel occupancy of 65.3%, it is important to highlight that this sector has been the main source of income for the state.However, Hurricane Otis severely impacted 80% of the hotel infrastructure, as reported by the Association of Hotels and Tourist Companies of Acapulco (AHETA). Additionally, the National Business Tourism Council of Mexico reported estimated losses of 15 billion dollars (15 billion) in terms of infrastructure damage.In the context of the tourism recovery for Acapulco, authorities indicated that, out of the 284 establishments with a hotel category, 80% have a capacity of up to 40 rooms. “According to Serfimex, the current gap in tourism may represent an opportunity for investors in the hotel, entertainment, restaurant, and service sectors” (Figueroa, 2023:1) [32].

7. DISCUSSION

The evolution of the total population of the municipality of Acapulco from 1900 to 2020 is presented as follows: in 1900, there were 4,932 people; in 1921, 5,768 inhabitants; in 1940, 9,993; in 1960, 46,149; in 1980, 301,902; in 2000, 620,656; in 2010, 673,479; and in 2020, it reached 779,556 inhabitants (Alva, 2023) [33] Meanwhile, by 2023, it reached a population of 852,622 inhabitants (INEGI, 2023) [34]. Population growth during this period can be explained by the fact that between 1900 and 1940, growth was slow due to the predominance of primary economic activities such as agriculture, livestock, fishing, and to a lesser extent, the initiation of tertiary economic activities, especially trade.

From 1960 onwards, the boom in trade, along with the flourishing of tourism, has led to continuous tourism growth, which until the year 2023 has had a direct and intensive impact on the resident and floating population, i.e., visitors and tourists. This growth has increased exposure to intense hydrometeorological phenomena, such as hurricanes, whose consequences have been devastating in the last 43 years. A notable example was the passage of Hurricane Pauline along the coasts of Guerrero, which at the time represented the most significant natural disaster in recent history for Acapulco (Rodríguez Estevez, 2017: 149) [7].

The bay of Acapulco, with its peculiar "shell-like" shape, its Tropical climate with summer rains (Aw), low-wave marine currents, and fine sands, has become a worldwide tourist icon, attracting both domestic and international tourists. Although precipitation is more frequent between June and November, it is precisely during the September-October period that the arrival of hurricanes to Acapulco has incurred a high cost in the recovery and restoration of affected infrastructure. Notable examples of these events are Hurricanes Pauline in 1997 and Ingrid-Manuel in 2013 and Otis 2023 (Table 1).

Table 1. Damages associated with Pauline, Ingrid-Manuel, and Otis in Acapulco, Guerrero

Damage	Hurricane Pauline	Tropical Storm Ingrid-Manuel	Hurricane Otis
DeadDamaged	102	169	50 more 30 missing
Evacuees	500	437	274 000
	9 000	6 500	548 000
	10 000	21 767	36 900
Economic losses	448 (millions of American dollars)	2 270 (millions of American dollars)	15 000 (millions of American dollars)
Road infrastructure	11 cuts or collapses	20 cuts or collapses	5 cuts or collapses
Affected tourists	Undetermined	40 000	50 000
Accumulated rain in 24	46	206	75
and 48 hours (mm)	360	226	150

Source:own elaboration with data from Rodríguez Esteves (2017, p. 147) [7]; Hernández (2023) [20], Guzmán (2023) [37]andConagua-Marca (2023) [38].

The data provided by official sources highlight economic losses as a factor linked to the intensity of damages in Acapulco, Guerrero. Affected strategic sectors include tourism, the road system, electrical infrastructure, the hydraulic system, and the education sector, both at the state and federal levels. Throughout history, federal and state support for the reconstruction of damages caused by tropical storms and hurricanes has been implemented during the year of the meteorological event's impact and the following year.

In the three meteorological events mentioned in Table 1, federal authorities provided meteorological information to early alert state, municipal governments, and the exposed population. However, despite these efforts, the information was not effective enough to prevent the disasters. Particularly critical was the lack of compliance in risk communication, which consists of five phases: preparation, initiation, control, recovery, and evaluation (Presidencia de la Nación, 2016) [35]. In practice, only the preparation phase was carried out, leaving the others in the background. This led to inadequate preparation by both authorities and the local population to cope with the emergency, resulting in disasters in the mentioned examples.

In the case of Otis, the initiation, control, recovery, and risk evaluation phases were addressed through coordinated actions under a single command that involved all government agencies to respond to the emergency. The federal government led efforts to mitigate the damages caused by flooding in areas such as Colonia Zapata and Ciudad Renacimiento in Acapulco, Avenida Costera Miguel Alemán, Costa Azul, Pie de la Cuesta, and Diamante.Assistance was extended to the affected people, even reaching the nearby municipalities of Coyuca de Benítez and San Marcos, where dredging and street, avenue, and canal cleaning activities were carried out. In addition, debris removal was conducted in various parts of the city and suburban areas, along with the recovery of priority urban infrastructure. These actions reflect a comprehensive response to address the aftermath of Hurricane Otis.

The context of vulnerability of residential constructions in Acapulco is high, primarily due to the constant growth in the number of residents, visitors, and tourists, as well as the development of infrastructure in areas identified in the Municipal Development Plans as high-risk areas to threats related to hydrometeorological natural phenomena. The root of

these disasters lies in the lack of attention to risk-associated factors, as well as the limited reduction of levels of social, environmental, and economic vulnerability. This situation hinders the achievement of local sustainability by the year 2030.

Therefore, it is crucial to unite efforts among all social actors with the aim of reducing vulnerability to damages caused by tropical storms and hurricanes. This collective effort seeks to strengthen the resilience of both the local population and tourists and visitors who began to be evacuated since Wednesday, Octuber 26, by “the Mexican Armed Forces who enabled two air posts to evacuate tourists and the population of Acapulco” (Yáñez, 2023, p. 4) [36], with the goal of achieving a sustainable city capable of facing any intense geographical phenomenon or event in the context of climate change.

8. CONCLUSIONS

The first issue pertains to vulnerability and risks associated with natural events, as the frequency of natural events such as hurricanes and tropical storms has left Acapulco exposed to a high level of vulnerability. Urban expansion without adequate consideration of risks associated with hydrometeorological phenomena has contributed to the degradation of infrastructure and increased the vulnerability of the local population and visitors.

The second issue involves governmental response and coordination in emergency cases. Government responses to natural disasters, such as Hurricane Otis, have demonstrated the importance of coordination and joint action among different government agencies. Despite challenges, there is evidence of efforts to address critical phases of initiation, control, recovery, and risk assessment. However, there is a highlighted need to improve risk communication and population preparedness.

Lastly, the need for long-term sustainability and resilience is emphasized. Local sustainability is threatened by the lack of attention to risk-associated factors and insufficient reduction of social, environmental, and economic vulnerability. The key to Acapulco's future lies in the necessity to unite efforts among all social actors to work on vulnerability reduction, promote resilience to extreme climatic events, and build a city capable of facing the challenges of climate change. These conclusions reflect the complexity of the situation in Acapulco and underscore the importance of long-term strategies to address vulnerability and strengthen the city's capacity to face intense climatic events.

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